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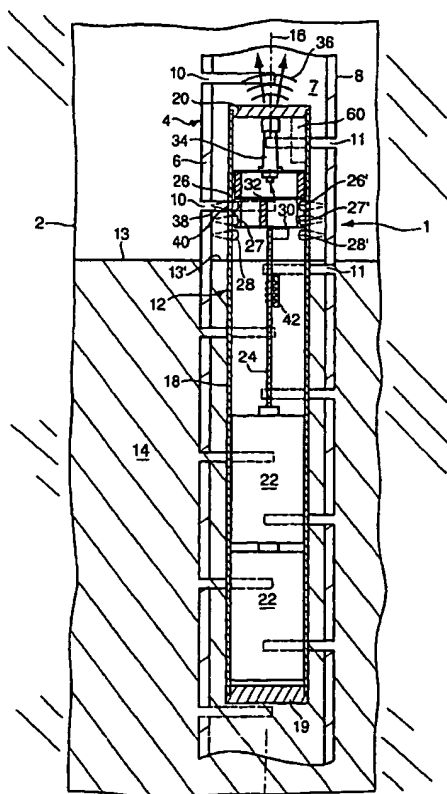
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(54) Title: **LIQUID LEVEL MEASUREMENT**



(57) Abstract: The present invention relates to the measurement of the level of a liquid, and particularly to the measurement of the water level in a borehole. A liquid level measurement device (1) comprises a processor (42) for calculating a liquid level (13), a float (12) and an elongate sleeve (4), the float (12) being free to float inside the sleeve (4) and to move along the length of the sleeve under the influence of a changing liquid level (13') inside the sleeve (4). The sleeve (4) has a plurality of graduations (10, 11) spaced along the length of the sleeve. The float has at least one optical sensor (26, 27, 28; 26', 27', 28') in communication with the processor (42) for sensing the graduations (10, 11) as the float (12) moves along the sleeve (4). The processor (42) is arranged to calculate from the sensed graduations (10, 11) changes in the level (13') of the liquid (14) inside the sleeve (4).

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## Liquid Level Measurement

## BACKGROUND

## 5 a. Field of the Invention

The present invention relates to the measurement of liquid level, and particularly to the measurement of the water level in a river, reservoir or the borehole of a well.

10

## b. Related Art

There are many known ways of measuring the level of water relative to a reference level, for example with respect to the bottom of a container, or relative to a nominal or average depth. Examples include float switches and potentiometer float devices. These instruments are ideally suited to shallow tanks, owing to the limited vertical travel of the sensing elements.

20 It is more difficult to measure the water level within deep water or a deep container, owing to the distance a moving float must travel as water level changes. Problems also arise if the water is not clear or clean. One known device uses a compressor to blow air down a pipe immersed in the water until the pipe is clear of water. The back-pressure of the water is then measured and the level of liquid calculated from that measurement. There could, however, be problems in using this method for deep water, such as found in boreholes, because the compressor would need to be much larger in order to clear a deep air pipe. In the case of measuring the level of river water, the currents from flowing water could affect the accuracy of the measurement.

30

Relatively precise, but expensive devices are known that use

various types of non-contact liquid level measurement, for example sonar, radar, laser and ultrasonic liquid level measurement devices. All such devices rely on there being a clear path, either in the liquid itself, or in the air above the liquid, through which acoustic or electromagnetic radiation may be passed. In addition to being expensive, such devices usually have high power consumption, and can be difficult to align in a constrained environment, for example a narrow well borehole. Many of such devices are also unsuitable for use in an environment where a sensor could be contaminated by algae growth or physically damaged, for example by contact with the wall of a narrow borehole, or in running water.

#### 15 SUMMARY OF THE INVENTION

It is an object of the present invention to provide a more convenient device and method for measuring the level of liquid, particularly the measurement of water level within a borehole.

20

According to the invention there is provided a liquid level measurement device, comprising an elongate sleeve, a float, an electric battery within the float, a processor for calculating a liquid level, the float being arranged to float freely inside and to move along the length of the sleeve under the influence of a changing liquid level inside the sleeve and the float having at least one non-contact sensor powered by the battery and in communication with the processor, wherein:

30

- a) the sleeve extends around the float;
- b) the sleeve has spaced along its length a plurality of

graduations that are optically visible from within the sleeve;

c) the or each non-contact sensor is an optical sensor  
5 arranged to sense the optically visible graduations as the float moves along the length of the sleeve;

d) the processor is arranged to calculate from the sensed graduations changes in the level of the liquid inside the  
10 sleeve.

The invention also provides a liquid level measurement system, comprising a liquid containing container and a liquid measurement device, wherein the liquid measurement device is  
15 according to the invention and is arranged within the container to measure changes in the level of liquid within the container.

The processor may be within the float, or within a separate  
20 component such as a base station in communication with the float. Processor calculations may alternatively be divided between microprocessors in the float and in base station.

The invention may be used to measure the water level of an  
25 open body of water, for example, the tide level at an ocean marina, or the level of a moving body of water such as a river. In one embodiment of the invention the device is used as part of a liquid level measurement system, comprising a liquid containing container with the liquid measurement  
30 device being arranged within the container to measure changes in the level of liquid within the container. Although the invention may be used with large diameter containers, such as above-ground or below-ground liquid storage tanks, the

invention is particularly useful with a container such as a borehole well, which may be relatively narrow, for example of the order of about 100 mm in diameter. The sleeve may have a smaller diameter, for example about 25 mm, and can then may  
5 be inserted directly into the borehole without the need for any further support or mounting.

Also according to the invention, there is provided a method of measuring liquid level in a liquid containing container  
10 using a liquid level measurement device, the liquid level measurement device being according to the invention, wherein the method comprises the steps of:

i) using one or more of the optical sensors to sense the  
15 relative movement of the float with respect to the graduations when the liquid level changes; and

ii) using the processor to calculate from the sensed movement of graduations a corresponding change of liquid  
20 level in the sleeve.

The float therefore floats within the sleeve and registers the relative movement of the float and sleeve as the level of the liquid changes. The use of a non-contact sensor,  
25 simplifies the construction and operation of the device.

The optical sensor may use one or more near-infrared light emitting diode/photodiode pairs. Such optical sensors can be pulsed for short times at a very low on/off duty cycle, which  
30 helps to conserve electrical power within the measurement unit.

In one embodiment of the invention, the float is cylindrical.

This provides the advantage that the float when inside the sleeve is free to rotate about its axis.

In its simplest form, the sleeve is tubular, and may be  
5 formed from relatively inexpensive materials, for example  
straight PVC tubing.

The graduations may be any mark, feature or material that can  
readily be detected by the non-contact sensor(s). In one  
10 embodiment of the invention, the graduations are slits  
through the sleeve that extend transversely to the direction  
of movement of the float inside the sleeve. Such slits may be  
readily visible to a non-contact optical sensor. The use of  
such slits through the sleeve is also particularly  
15 advantageous in the case where the sleeve is in a container  
holding the liquid. Any changes to the liquid level will  
immediately result in a flow of liquid through the slits from  
the exterior to the interior of the sleeve, therefore  
allowing for an automatic and rapid correlation between the  
20 level of the liquid inside the container and the level of the  
float floating on the liquid inside the sleeve.

The sleeve may extend along an axis, for example being  
cylindrical, and the float may then be free to rotate about  
25 this axis. The float may have a plurality of non-contact  
sensors spaced apart around the axis, the angular separation  
between these spaced apart sensors and the extent of each  
graduation around the axis being such that at least one of  
the non-contact sensors is able to sense each of the  
30 graduations as the float moves along the sleeve. Neighbouring  
graduations spaced along the length of the sleeve may then be  
rotated relative to one another around the sleeve axis.

## BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be described in greater detail, and by way of example only, with reference to the accompanying drawings, in which:

5

Figure 1 is a partial cross-section along a longitudinal axis of a liquid level measurement device according to a first embodiment of the invention, having a cylindrical tubular sleeve with graduation slits, inside of which floats a cylindrical float sensor;

10

Figure 2 is a partial cross section of the device of Figure 1, used to measure the depth of water within a borehole;

15

Figure 3 is transverse cross-section of a liquid level measurement device according to a second embodiment of the invention, having a square cross-section tubular sleeve with graduation slits inside of which floats an octagonal cross-section float sensor;

20

Figure 4 is a transverse cross-section of a liquid level measurement device according to a second embodiment of the invention, similar to that shown in Figure 3, but having a pair of longitudinal strips with graduations inside the sleeve;

25

Figure 5 is a block circuit diagram of the functioning of the float sensor of Figure 3; and

30

Figure 6 is a block circuit diagram of a base station for the liquid level measurement system.

## DETAILED DESCRIPTION



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Figure 1 shows part of a liquid level measurement system 1 for an agricultural borehole 2, according to a first embodiment of the invention. The system 1 comprises a hollow tubular sleeve 4 having a cylindrical outer wall 6 with smooth inner facing and outer facing cylindrical surfaces 7,8. A number of transverse slits 10,11 are cut through the wall 6 at regularly spaced intervals.

A float sensor 12 floats within the sleeve 4, the relative vertical position between the sleeve 4 and the float sensor 12 being determined by the water level 13 of a body of water 14 within the borehole 2.

The float sensor 12 is cylindrical in shape, having a diameter sufficiently less than the inner diameter of the sleeve 4 so that the float sensor 12 can easily move vertically up or down along a longitudinal axis 16 of the sleeve 4. The sleeve 4 is therefore concentric with the float and acts as a float guide. Because the sleeve 4 is a body extending substantially fully around the float sensor 12, the sleeve 4 affords the maximum mechanical protection to the float sensor 12.

The float sensor 12 has a tubular aluminium body 18 with impermeable plastic end caps 19,20. A pair of lithium 3.6 Volt batteries 22 are housed within a lower portion of the body 18 and provide electrical power for a number of electronic and optoelectronic components, including a processor circuit board 24 three sets of at least two and preferably three non-contact infra-red sensors, two sets of which 26,27,28;26',27',28' are visible in the drawing, a sensor circuit board 30 for controlling the infra-red sensors, and a radio transmitter circuit board 32 connected

to an antenna 34 for transmitting radio signals 36 upwards through one of the plastic end caps 20.

5 The infra-red sensors 26,27,28;26',27',28' each comprise a transmitter LED matched to a photodiode receiver. Infra-red optical radiation 38 is focused by an integral focusing lens 40 so that optical radiation 38 is directed towards the inner surface 7 of the tubular wall 6. If the focused optical radiation 38 is incident upon the inner surface 7, then a  
10 significant fraction of this will be reflected or scattered and collimated by the lens 40 and hence detected by the infra-red photodiode. If, on the other hand, the optical radiation 38 is directed towards one of the slits 10,11, then there will be a relatively low level of reflected or scattered optical  
15 radiation detected by the photodiode. The infra-red sensors 26,27,28;26',27',28' each have a spacing in the vertical direction such that only one of the sensors in each set of three sensors can detect a slit 10,11 at any one time.

20 Each of the slits 10,11 subtends an angle about the axis 16 of slightly more than  $180^\circ$ . Neighbouring slits 10,11 in the vertical direction are staggered by  $180^\circ$  in a symmetrical fashion. In the present example, the float sensor 12 has three sets of sensors 26,27,28;26',27',28' to provide for a  
25 certain level of redundancy in the case that the float sensor 12 begins to rotate about the vertical axis 16. It would, however, be possible to use just two sets of sensors spaced apart by  $180^\circ$ .

30 The arrangement between the slits 10,11 and the vertically spaced three sensors 26,27,28;26',27',28' is such that as the float sensor 12 moves up and down the axis 16 of the sleeve 4, the sensors will be able to register both the presence of

each slit 10,11, as well as the relative direction of motion between the float sensor 12 and the sleeve 4. Each sensor 26,27,28;26',27',28' is in communication with a microprocessor 42 on the processor circuit board 24. The  
5 microprocessor 42 keeps track of the passage of the slits 10,11 and from the regular spacing of these graduations is able to calculate the vertical movement of the float sensor 12 within the sleeve 4. In order to minimise power consumption, the infra-red sensors 26,27,28;26',27',28' are  
10 pulsed at a low duty cycle. If the microprocessor 42 detects movement past one of the slits 10,11, then the microprocessor 42 activates via the transmitter circuit board 32 a radio transmission 36 from the antenna 34.

15 Referring now also to Figure 2, such a radio transmission 36 can be detected by a base station 50 having a receiver antenna 46 that projects in through a cap 48 at the top of the borehole 2. The base station 50 can then receive the radio signal 36 and transmit 52 this to a central monitoring  
20 station or a communications network (not shown) for a number of similarly monitored boreholes. Optionally, the base station 50 may transmit 54 to the float sensor 12 in order to communicate information to the float sensor, in particular a nominal value for initial depth for the water level 13 within  
25 the borehole 2.

The float sensor 12 is weighted down by the batteries 22, and so naturally floats with the antenna 34 in an uppermost portion of the sensor 12. In most applications, the sleeve 4  
30 will extend essentially vertically through the body of water 14.

The transverse slits 10,11 provide the advantage of making

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the sleeve 4 more flexible, so that it can bend more easily to accommodate the shape of an adjacent wall, and so that it can more readily be rolled up when not in use or prior to installation.

5

The slits 10,11 also allow the ingress or egress of water as the water level 13 changes. For a particular number of slits 10,11, there will be a maximum rate of flow through the slits, and so the water level 13' inside the sleeve 4 may  
10 change more slowly than the water level 13 outside the sleeve. This, however, provides the advantage that the optical pulse rate from the sensors 26,27,28;26',27',28' can be set so that this does not exceed that required by the maximum expected rate of change of water level 13' inside the  
15 sleeve 4.

It will, at intervals, be necessary to retrieve the float sensor 12 from within the sleeve 4, in order to change the batteries 22. One way in which this can be done is by  
20 providing a magnet 60 in an upper portion of the float sensor 12. Such a magnet 60 would, however, need to be positioned so that this did not interfere with radio transmissions 36 from the antenna 34.

25 Another way in which the float sensor 12 can be retrieved, is if the sleeve 4 has an end stop 62, such as a sealed or partially sealed end to the sleeve 4. The sleeve can have a sufficient length so that it is readily accessible near the top of the borehole 2. As the sleeve 4 is retrieved from the  
30 borehole 2, water 14 will flow out of the sleeve 4 with the level of the float sensor 12 dropping until it comes against the end stop 62. The float sensor 12 can then be retrieved from the sleeve 4 once this has been fully removed from the

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borehole 2. The lower end cap 19 may be provided with threads (not shown) so that this can readily be removed in order to change the batteries 22.

5 A particular advantage of the end stop 62 is that the float sensor 12 can be positioned at this end of the sleeve 4 when this is initially inserted into the borehole 2. As the sleeve 4 is fully inserted into borehole 2, the float sensor 12 will rise up the sleeve 4 as water enters the sleeve 4. The float  
10 sensor 12 can then be calibrated initially to a reference depth equal to that of the end stop 62 when this is fully inserted in the borehole 2. The processor 42 then is initially calibrated to the true depth of the water level 13 within the borehole 2.

15

The liquid level measurement system 1 need not interfere with other devices commonly used with borehole, for example a pump unit 64 at the base 66 of the borehole 2, or an electrical power line 68 or water supply line 70 between the pump unit  
20 64 and end cap 48 of the borehole 2.

The sleeve 4 can inexpensively be formed from 3 mm thick PVC tubing, having an internal diameter of 25 mm. The float sensor 12 can then have an external diameter of about 20 mm,  
25 and a length of about 200 mm. The vertical spacing between neighbouring slits 10, 11 may be of the order of about 20 mm. Such a spacing allows the float sensor 12 to monitor the water level 13 within the borehole 2 to a high degree of accuracy compared with many other water level measurement  
30 systems. A particular advantage of the invention is that the sleeve can be manufactured relatively inexpensively, and in long continuous lengths. In a typical borehole, the sleeve may be between about 10 m to 250 m long, although the

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invention is applicable to lengths greater than or shorter than these distances.

It should be noted that the tasks performed by the processor  
5 42 could be split amongst one or more electronic processing  
devices, either within the float sensor 12 or split between  
the float sensor 12 and base station 50. In this sense, the  
base station 50 may comprise part of the liquid level  
measurement device 1. However, because radio transmissions 36  
10 from the float sensor 12 to the base station 50 consume a  
relatively large amount of electrical power, it is preferred  
if most or all of the processing is done within the float  
sensor 12, with changes in water level 13 being communicated  
to the base station 50 when and as necessary.

15  
In some applications, particularly the measurement of the  
level of storage tanks or river level measurement, the liquid  
level measurement system may be in communication with a  
network of similar sensors. In some cases, the base station  
20 may be at some distance from the sleeve, for example on a  
river bank.

The liquid level measurement systems described above are  
relatively inexpensive to construct, and are convenient to  
25 use in many situations, particularly where there is limited  
space or availability of mains electric power, such as with  
agricultural boreholes. The invention may also be useful in  
other remote locations, for example the measurement of water  
levels at a river or a marina. In some cases, it may be  
30 desirable to limit or to filter the flow of liquid into the  
sleeve. In such cases, the graduations may be reflected or  
painted stripes on the sleeve for example on an outer surface  
of an optically transparent sleeve. A single liquid entrance

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may then be provided at one point on the sleeve so that the liquid level inside the sleeve remains in communication with that on the outside of the sleeve.

5 Figure 3 shows a transverse cross-section of a liquid level measurement device 101 according to a second embodiment of the invention, in which features corresponding to the first embodiment 1 are indicated by reference numerals incremented by 100. The device 101 is similar in function and operation  
10 to the first embodiment 1, but has a square cross-section tubular sleeve 106 having four sides 96,97,98,99, just one of which 96 has a plurality of transversely extending graduation slits 110 spaced longitudinally along the length of the side 96.

15 A float sensor 112 floats within the sleeve 104. At least 2 non-contact infra-red sensors 126 are longitudinally spaced apart in the centre of one side 71 of the float sensor 112. Therefore, as the float sensor 112 moves under the action of  
20 a changing liquid level, reflected or scattered optical radiation 138 is used to detect the passage of the series of slits 110. The view of Figure 3 is in a plane perpendicular to an axis 116 of the sleeve 104 and float sensor 112

25 The sleeve 104 is formed from 38 mm square section plastic tube. The thickness of the sleeve wall 106 may be between about 1 mm to 3 mm. The advantage of using a square section sleeve 104 is that the float sensor 112 can therefore also be of essentially square section so that the float 112 no longer  
30 is able to rotate in the sleeve 104. In this example, the float sensor is of roughly octagonal cross-section. Therefore, a single column of optical sensors 126 may be used, rather than the three columns used in the first

embodiment. If one side 96 of the sleeve 104 is being used for graduations of a first spacing, for example 10 mm, then another side 97,98,99 may have graduations of a finer spacing, for example 2 mm to 3 mm. In this case, the float  
5 sensor 112 would have another set of optical sensors 126 arranged opposite the other face 72. However, in many applications it would be better to have a reduced number of optical sensors 126 in order to reduce the battery load and also to increase the strength of the sleeve.

10

Figure 4 shows a third embodiment of a liquid level measurement system 201, similar to the second embodiment 101, in which features similar to those of the second embodiment are indicated by reference numerals incremented by 100. The  
15 third embodiment 201 differs from the second embodiment 101 in having a square sleeve 204 with no slits 110 or other such apertures formed in the wall 206 of the sleeve 204. In place of slits through the sleeve 204, the sleeve has a pair of separate graduation strips 210,211 held inside the sleeve 204  
20 against opposite parallel inner faces 207 of the sleeve 204 by means of opposite inwardly projecting rails 75 on the inner surface 207 of the sleeve 204. The rails 75 together with the opposite sides 196,199, form two opposite pairs of channels 76, which hold the opposite graduation strips  
25 210,211 in place against the inner wall 207 of the sleeve 204.

The graduation strips 210,211 may be painted, textured, or cut through with longitudinally spaced slits (not shown) in  
30 order to present optically visible graduations to oppositely directed columns of optical sensors 226,226' arranged in opposite sides 171,173 of the octagonal cross-section float sensor 212.



In either of the second or third embodiments 101,201, self calibration can be built into the device by forming further calibration graduations at known distances, for example every 1 m along any face of the sleeve that is not being used for fine measurement purposes. Such additional calibration graduations could be detected by using a single optical sensor (not shown) in the float sensor 112,212. Such an additional optical sensor could conveniently be provided on any of the sides of the float sensor 112,212 not being used to detect finer graduations.

Figure 5 shows a block circuit diagram of the functioning of float sensor 112 of Figure 3. The functioning of the float sensor 212 of the third embodiment 201 is similar, and so will not be separately described.

The float sensor 212 has a 3.6 volt battery 122 provided in a lower portion of the float sensor 112, which provides physical ballast to the float sensor 112 so that this naturally floats up right within the sleeve 104. The battery 122 provides electrical power 78 to a power supply circuit 79 which converts the battery voltages to voltages required by the other electrical components within the float sensor 112. These other electrical components include a microprocessor 142, an optical sensor circuit 80 which drives the vertically stacked optical sensors 126,127, and a radio transmitter circuit 132.

The float sensor 112 includes additionally a tip-over switch circuit 81, the function of which is to isolate the battery 122 in the event that the float sensor 112 is inverted. This provides a convenient way of conserving battery power when

the float sensor 112 is not in use.

In order to conserve electrical power, the optical sensor circuit 80 pulses the optical sensors 126, 127 to produce  
5 short bursts of infra-red light 138. The optical sensor circuit 80 operates under the control 82 of the microprocessor 142 which also receives input from the optical sensor circuit as the optical sensors 126, 127 sense the vertical passage of graduations. The microprocessor 142 then  
10 sends information 83 to the radio transmitter circuit 132, which transmits 136 this information from an antenna 134.

The complete float system 112 is enclosed in a waterproof moulding with a screw fastened bottom (not shown) to allow  
15 the battery 122 to be changed.

As with the first embodiment 1, the sleeves 104, 204 and float sensors 112, 212 of the second and third embodiments 101, 201 may be used to measure water level in a borehole, reservoir  
20 or a river. The system will normally include the base station 50, shown in more detail in Figure 6. The base station 50 is preferably powered by a lead-acid battery 82 which is recharged by a solar panel 83 via a power supply circuit 84. The power supply circuit 84 also regulates the output from  
25 the battery 82 and supplies a regulated voltage to other electrical components, including an LCD display and keypad 85 for manual control of the base station 50 and float sensor 12, 112, 212, a microprocessor 86, a memory/data logging section 87, a data communications circuit 88 to interface to  
30 a computer 95 a radio receiver circuit 89, a radio transmitter modem circuit 90 and a modem 91 for a communication over a telephone line 92.

The radio receiver circuit 89 collects the data transmitted 136 from the float sensor 12,112,212 and feeds this to a microprocessor 86. In order to conserve power, the microprocessor 42, 142 in the float sensor may not calculate  
5 the depth of the liquid. Instead, the microprocessor 86 in the base station 50 counts pulses received from the float sensor 12, 112, 212, and calculates from this the depth of the liquid. The changing depth of the liquid may then be stored in the memory 87 and/or transmitted externally via the  
10 radio modem 90 or telephone modem 91.

User input can be provided via the computer 95 and data communications circuit 88. For example, information such as offsets may be entered into calculations performed within the  
15 base station 50. In addition low or high alarm levels may be manually or automatically set to provide an alert for predetermined low or high liquid levels. Such data may be entered by the user, or programmed and downloaded via either of the modems 90,91 into flash memory.

20

The invention therefore provides a number of convenient and economical ways for measuring or monitoring the level of still or running water, for example in a well, reservoir or river.

25

It is appreciated that certain features of the invention, which are, for clarity, described in the context of separate embodiments, may also be provided in combination in a single embodiment. Conversely, various features of the invention  
30 which are, for brevity, described in the context of a single embodiment, may also be provided separately, or in any suitable combination.

It is to be recognized that various alterations, modifications, and/or additions may be introduced into the constructions and arrangements of parts described above without departing from the scope of the present invention, as  
5 defined by the appended claims.

## Claims:

1. A liquid level measurement device (1,101,201), comprising an elongate sleeve (4,104,204), a float (12,112,212), an electric battery (22,122) within the float (12,112,212), a processor (42,86,142) for calculating a liquid level (13), the float (12,112,212) being arranged to float freely inside and to move along the length of the sleeve (4,104,204) under the influence of a changing liquid level (13') inside the sleeve (4,104,204) and the float (12,112,212) having at least one non-contact sensor (26,27,28,26',27',28',126,127,226,226') powered by the battery (22,122) and in communication with the processor (42,86,142), wherein:
- 15 a) the sleeve (4,104,204) extends around the float (12,112,212);
- b) the sleeve (4,104,204) has spaced along its length a plurality of graduations (10,11,110) that are optically visible from within the sleeve (4,104,204);
- 20 c) the or each non-contact sensor is an optical sensor (26,27,28,26',27',28',126,127,226,226') arranged to sense the optically visible graduations (10,11,110) as the float (12,112,212) moves along the length of the sleeve (4,104,204);
- 25 d) the processor (42,86,142) is arranged to calculate from the sensed graduations (10,11,110) changes in the level of the liquid inside the sleeve (4,104,204).
- 30
2. A liquid level measurement device (1) as claimed in

Claim 1, in which the float (12) is cylindrical.

3. A liquid level measurement device (1) as claimed in  
Claim 2, in which the sleeve (4) has a cylindrical inner  
5 surface (7) which is concentric with the float (12).

4. A liquid level measurement device (1,101,201) as claimed  
in any preceding claim, in which the sleeve (4,104,204) has  
towards one end a stop (62) to prevent the float (12,112,212)  
10 from exiting the sleeve (4,104,204).

5. A liquid level measurement device (1,101,201) as claimed  
in any preceding claim, in which the sleeve (4,104,204) is  
tubular.

15

6. A liquid level measurement device (1,101) as claimed in  
any preceding claim, in which the graduations are slits  
(10,11,110) through the sleeve (4,104) that extend  
transversely to the direction of movement of the float  
20 (12,112) inside the sleeve (4,104).

7. A liquid level measurement device (1) as claimed in any  
preceding claim, in which the sleeve (4) extends along an  
axis (16), and the float (12) when in the sleeve (4) is free  
25 to rotate about the axis (16), wherein the float (12) has a  
plurality of optical sensors (26,27,28;26',27',28') spaced  
apart around the axis, the angular separation between the  
spaced apart sensors (26,27,28;26',27',28') and the extent of  
each graduation (10,11) around the axis (16) being such that  
30 at least one of the optical sensors is able to sense each of  
the graduations (10,11) as the float (12) moves along the  
sleeve (4).

8. A liquid level measurement device (1) as claimed in Claim 7, in which neighbouring graduations (10,11) spaced along the length of the sleeve (4) are rotated relative to one another around the sleeve axis (16).

5

9. A liquid level measurement device (1,201) as claimed in Claim 8, in which there is a pair of optical sensors (26,27,28,126;26',27',28',126') on opposite sides of the float axis (16,216), and neighbouring graduations (10,11) are rotated 180° relative to one another.

10

10. A liquid level measurement device (1) as claimed in Claim 9, in which the sleeve (4) has a cylindrical wall (6), and each of the graduations (10,11) extends through an arc of the wall extending at least 180°.

15

11. A liquid level measurement device (101,201) as claimed in any of Claims 1 to 6, in which the sleeve (104,204) extends along an axis (116,216) and has a non-circular inner diameter, the fit between the float (112,212) and the sleeve (104,204) being such that the float (112,212) when in the sleeve (104,204) is not free to rotate about the axis (116,216).

20

12. A liquid level measurement device (101,201) as claimed in Claim 11, in which the sleeve (104,204) has a plurality of sides (96-99;196-199) around the axis (116,216), and the graduations (110) are provided along the length of at least one of said sides (96;196,199).

25  
30

13. A liquid level measurement device (101,201) as claimed in Claim 12, in which the sleeve (104,204) is square or rectangular in cross-section through the axis (116,216).

14. A liquid level measurement device (101,201) as claimed  
in any of Claims 11 to 13, in which the float (112,212) has a  
plurality of sides (96-99,196-199) around the axis (116,216),  
5 and at least one of the optical sensors (126,226,226') is  
provided on at least one (96,196,199) of said sides.

15. A liquid level measurement device (201) as claimed in  
Claim 14, in which the float (212) has at least one of the  
10 optical sensors (226,226') on opposite sides (196,199) of the  
float (212).

16. A liquid level measurement device (1,101,201) as claimed  
in any preceding claim, in which the or each optical sensor  
15 comprises at least two optical sensing devices  
(26,27,28,26',27',28',126,127,226,226') spaced longitudinally  
along the float (12,112,212), each of the sensing devices  
being capable of sensing the presence of the graduations  
(10,11,110) so that the processor (42,86,142) can calculate  
20 from the sensed graduations (10,11,110) the direction of  
motion of the float (12,112,212) relative to the graduations  
(10,11,110).

17. A liquid level measurement device (1,101,201) as claimed  
25 in Claim 16, in which the optical sensing devices  
(26,27,28,26',27',28',126,127,226,226') are arranged in a  
row, the row extending in a plane along which the sleeve  
(4,104,204) extends.

30 18. A liquid level measurement device (1,101,201) as claimed  
in any preceding claim, in which the battery (22,122) is  
positioned in a lower portion of the float (12,112,212), and  
the or each optical sensor is positioned in an upper portion



of the float (12,112,212).

19. A liquid level measurement device (1,101,201) as claimed in any preceding claim, comprising a base station with a  
5 radio receiver, the float (12,112,212) having a radio transmitter in radio communication with the receiver so that liquid level data are communicated from the float (12,112,212) to the base station.

10 20. A liquid level measurement device (1,101,201) as claimed in any preceding claim, in which the processor (42,142) is housed within the float (12,112,212).

15 21. A liquid level measurement device (101,201) as claimed in any preceding claim, in which the float (112,212) includes a tip-over switch (81) that switches electrical power from the battery (82) between on and off when the float (112,212) is inverted.

20 22. A liquid level measurement system, comprising a body of liquid (14) and a liquid measurement device (1,101,201), wherein the liquid measurement device (1,101,201) is as claimed in any preceding claim, and is arranged to measure changes in the level (13) of the body of liquid (14).

25

23. A liquid level measurement system as claimed in Claim 22, in which the body of liquid (14) is in a borehole (2).

24. A liquid level measurement system as claimed in Claim 23  
30 or Claim 23, in which the sleeve (4,104,204) is between 10 m and 250 m long.

25. A method of measuring liquid level (13) in a liquid

containing container (2) using a liquid level measurement device (1,101,201), the liquid level measurement device (1,101,201) being as claimed in any of Claims 1 to 21, wherein the method comprises the steps of:

5

i) using one or more of the optical sensors (26,27,28,26',27',28',126,127,226,226') to sense the relative movement of the float (12,112,212) with respect to the graduations (10,11,110) when the liquid level (13) changes;

10 and

ii) using the processor (42,86,142) to calculate from the sensed movement of graduations (10,11,110) a corresponding change of liquid level (13') in the sleeve (4,104,204).

15

26. A method as claimed in Claim 25, in which the processor (42,86,142) calculates the change of liquid level (13) relative to an initial known liquid level.

20

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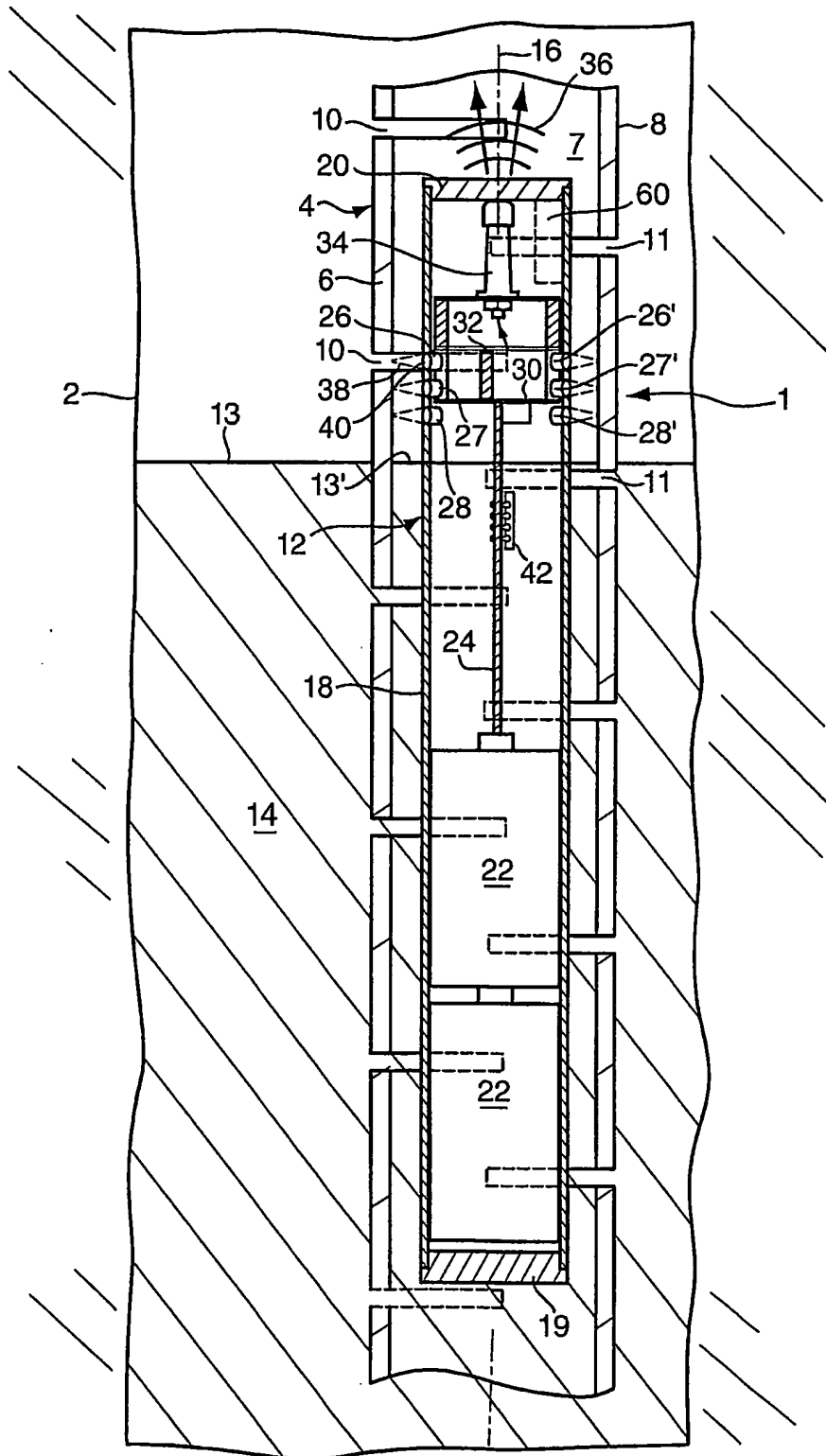


Fig. 1

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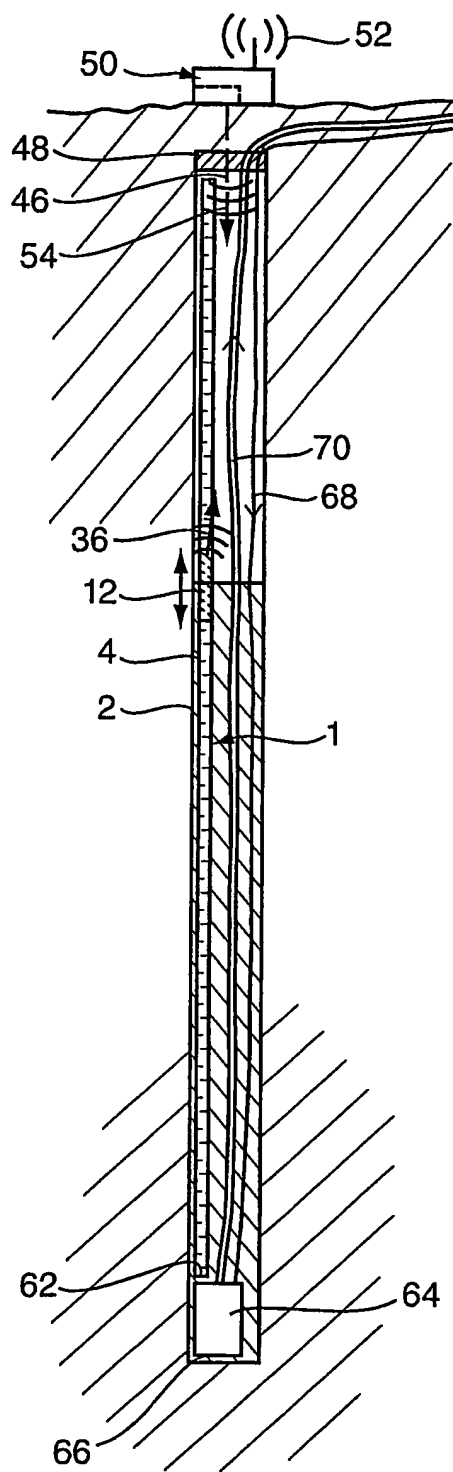
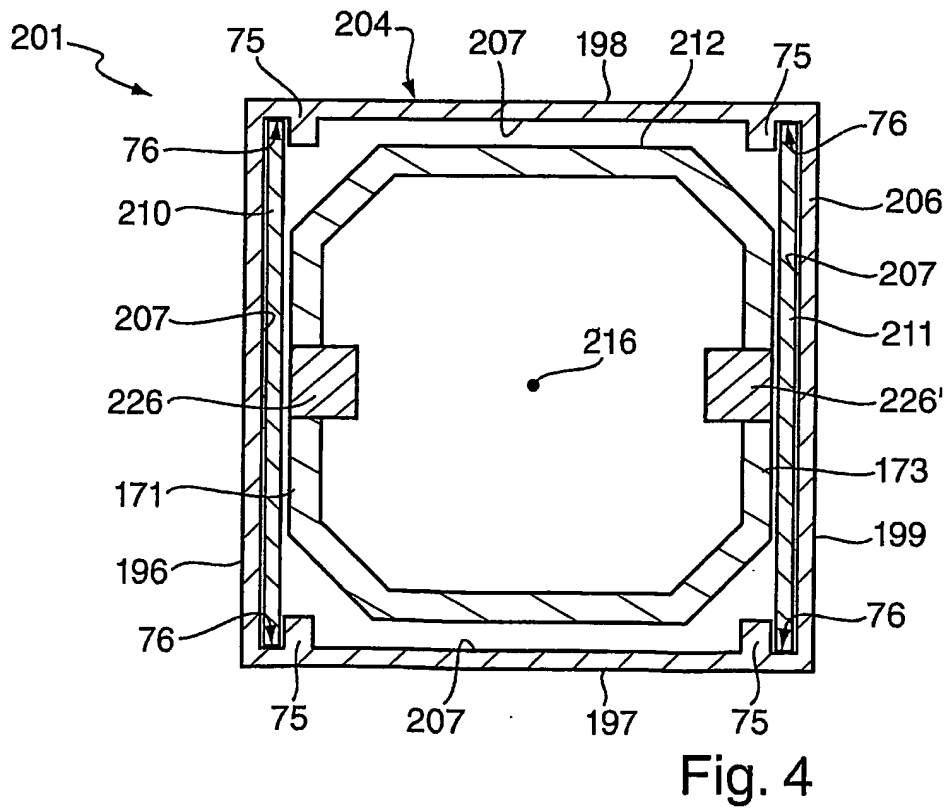
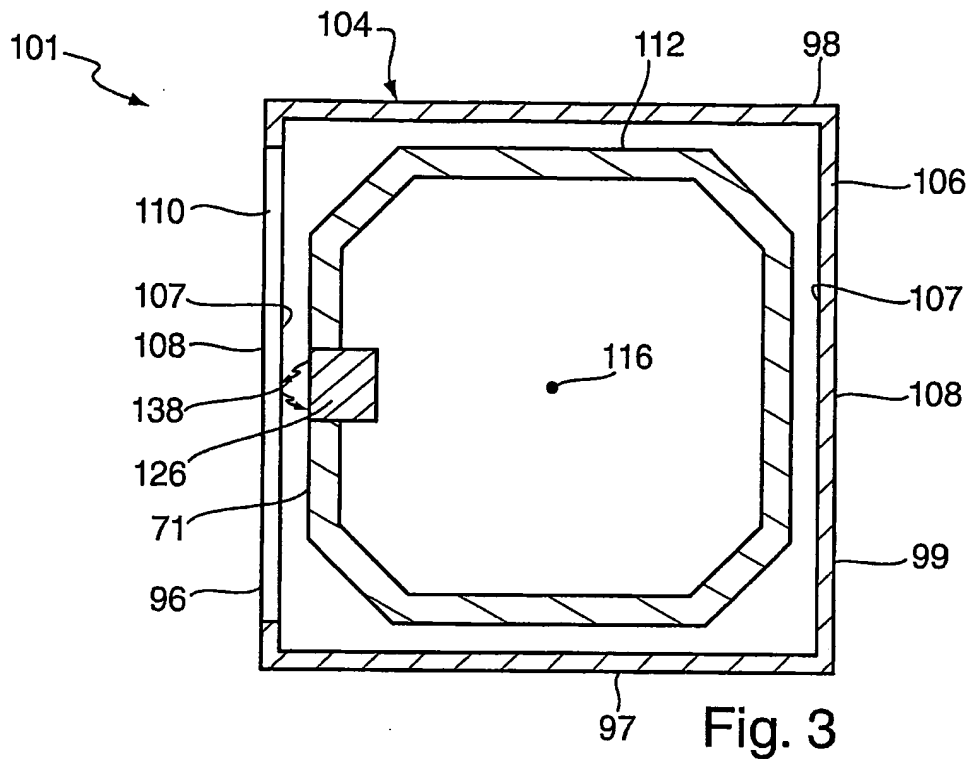


Fig. 2

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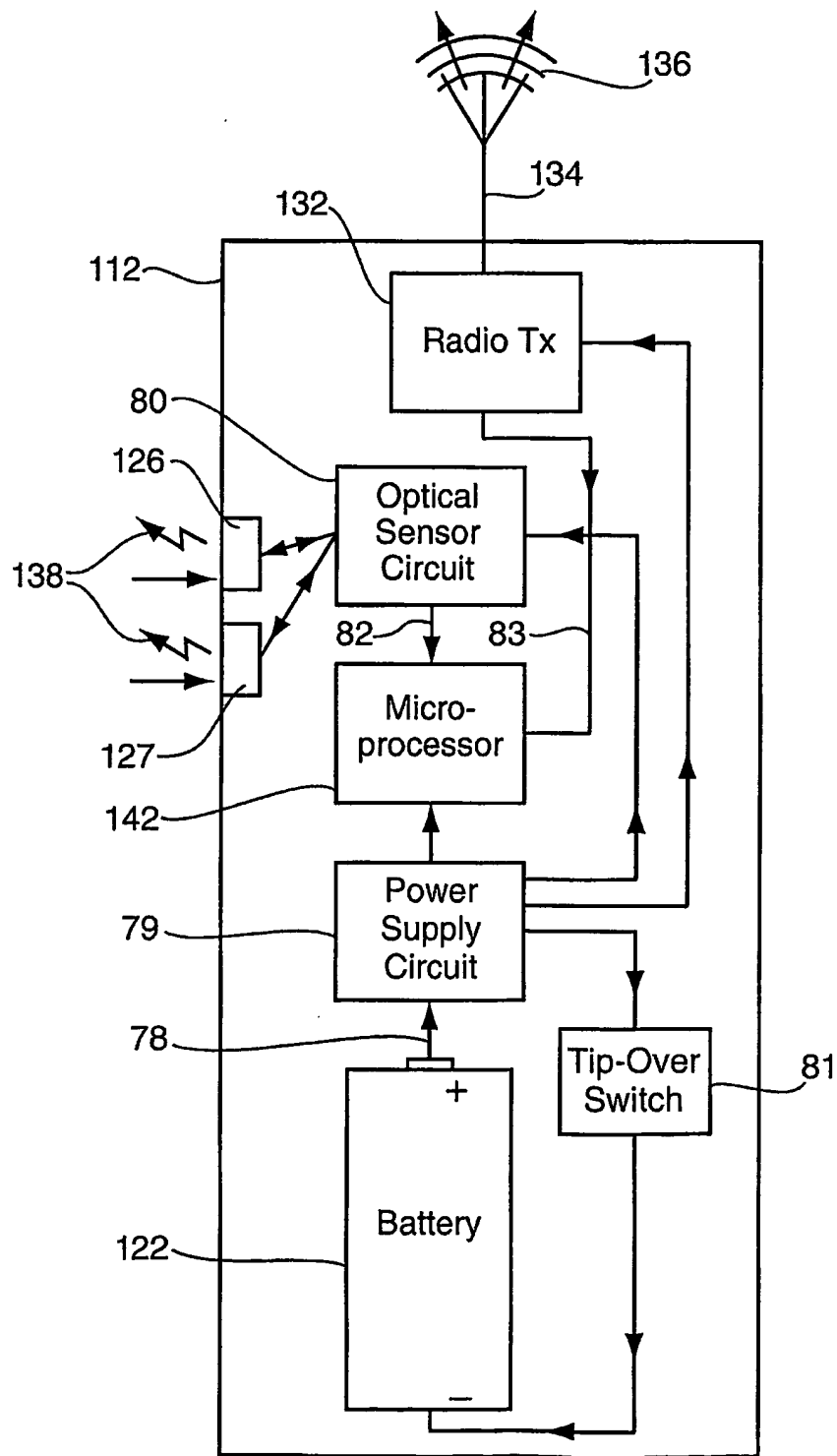


Fig. 5

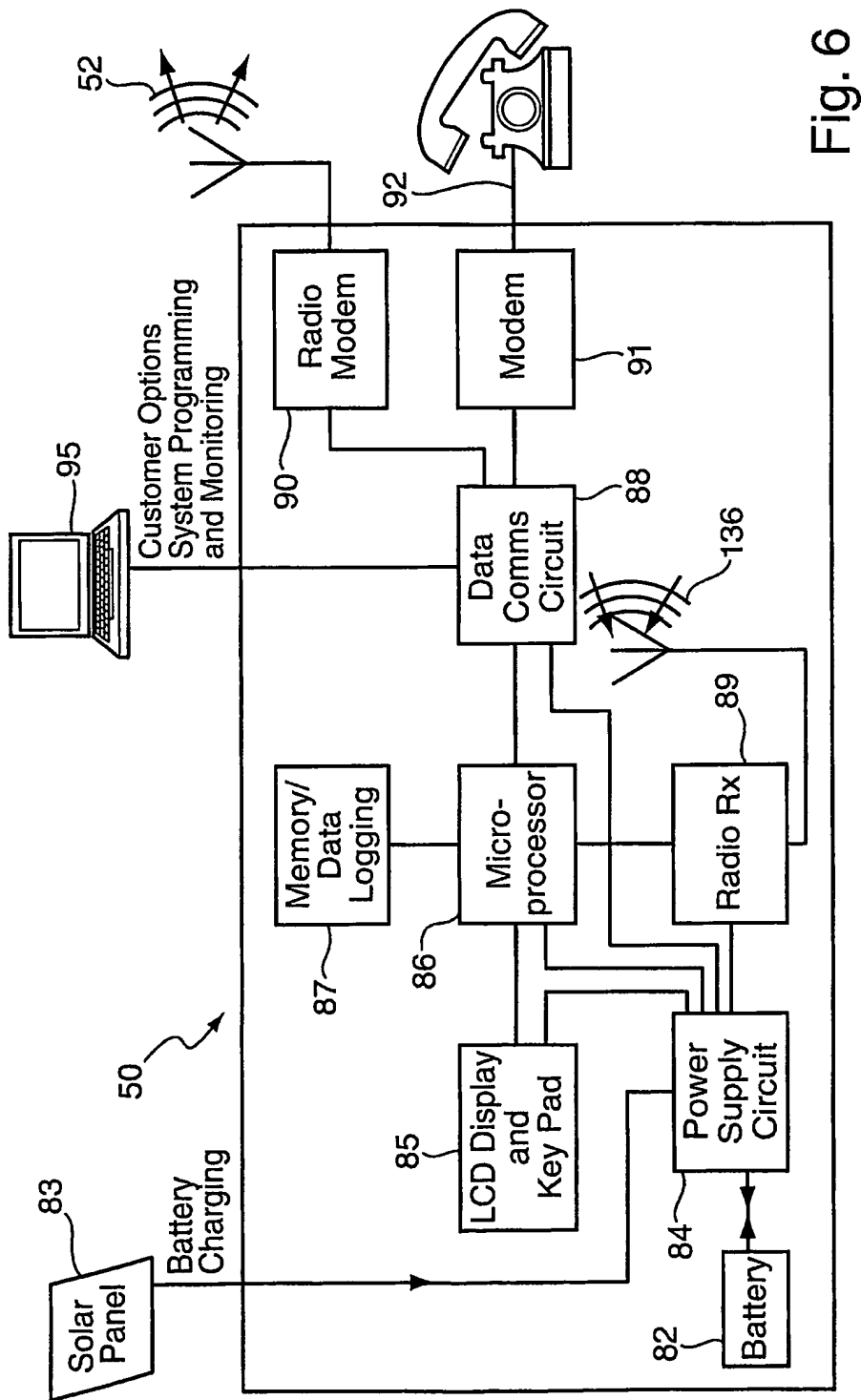


Fig. 6

# INTERNATIONAL SEARCH REPORT

International Application No  
PCT/GB 03/02133

A. CLASSIFICATION OF SUBJECT MATTER  
IPC 7 E21B47/04 G01F23/68

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 E21B G01F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 483 831 A (STEINER GEORGE A) 16 January 1996 (1996-01-16) column 3, line 2 -column 4, line 5; figures 3,5,8	1,22,25
A	US 5 874 899 A (BARMORE JR GASTON C ET AL) 23 February 1999 (1999-02-23) column 3, line 20 -column 5, line 56; figures 1-5	1,22,25

☐ Further documents are listed in the continuation of box C.

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Date of the actual completion of the international search

11 September 2003

Date of mailing of the international search report

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# INTERNATIONAL SEARCH REPORT

International publication No  
PCT/GB 03/02133

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
US 5483831	A	16-01-1996	NONE	
US 5874899	A	23-02-1999	CA 2246452 C	29-04-2003

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